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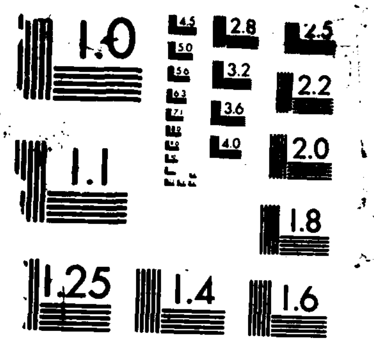

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An approach toward the automated extraction of terrain features from synthetic aperture radar (SAR) imagery is the development of sets of descriptors that uniquely and unambiguously characterize each feature. This investigation involves a detailed examination of 701 SAR image examples covering 29 types of man-made and natural terrain features. The descriptors represent attributes of the radar signatures from terrain features. The descriptors are developed by means of which image analysts identify the terrain features. The development of descriptors is guided by the objectives that the descriptors can be easily recognized and identified by untrained personnel and that they provide a baseline for interactive and automated feature extraction. The number of selected descriptors at this point is 52 and may change as the research progresses. A feature class is characterized by specific sets of descriptors. Because radar signatures of the same type of terrain feature will vary it is necessary to establish combination rules for descriptor sets. It was found that although 478 sets of descriptors were required for the identification of the 29 types of features, all descriptor sets were unique and all of the

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An approach toward the automated extraction of terrain features from synthetic aperture radar (SAR) imagery is the development of sets of descriptors that uniquely and unambiguously characterize each feature. This investigation involves a detailed examination of 701 SAR image examples covering 29 types of man-made and natural terrain features. The descriptors represent attributes of the radar signatures from terrain features. The descriptors are developed by means of which image analysts identify the terrain features. The development of descriptors is guided by the objectives that the descriptors can be easily recognized and identified by untrained personnel and that they provide a baseline for interactive and automated feature extraction. The number of selected descriptors at this point is 52 and may change as the research progresses. A feature class is characterized by specific sets of descriptors. Because radar signatures of the same type of terrain feature will vary it is necessary to establish combination rules for descriptor sets. It was found that although 478 sets of descriptors were required for the identification of the 29 types of features, all descriptor sets were unique and all of the sets characterizing any individual feature could be formulated in a single Boolean expression. A knowledge-based expert system was developed that inputs descriptor sets and outputs terrain feature classifications. The newly developed concepts are being tested at the U.S. Army Intelligence School

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RADAR DESCRIPTORS FOR THE CLASSIFICATION OF TERRAIN FEATURES (U)

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INTRODUCTION

The task of detection, recognition, classification, and identification of man-made and natural terrain features from radar imagery is performed by experienced image analysts. Image analysts utilize mental processes, often not clearly understood by themselves, to extract the required information from radar imagery. Modern radar systems are capable of collecting large amounts of image data which require more image analysts for timely and efficient analysis. Because experienced image analysts are in short supply a widening gap between data acquisition and data analysis has developed. Thus, there is a need for the development of new capabilities that will shorten the training of image analysts, provide better tools for experienced analysts, and for automated and interactive image analysis. This paper deals with a new approach to attack the problem of interactive and automated feature extraction from radar imagery. The report covers the work accomplished during the period April 1984 to February 1986. The work was supported by the U.S. Army Intelligence School, Fort Huachuca, Arizona, and by the contractor Autometric Inc., Falls Church, Virginia.

RADAR FEATURE DESCRIPTORS

Radar signatures of terrain features are the radar images of terrain features on the ground. Experienced image analysts analyze terrain features on radar images by examining the brightness and geometry of the radar signatures. They perform eyeball measurements, search for specific characteristics, and evaluate the context and contrast between background and feature. The image analyst may also use radar keys to support his analysis. Radar keys are radar images of features or targets that can be used for comparing the signature under investigation with the keys. The observations are analyzed, evaluated, and compared with the past experience of the analyst. The results of the observations and analysis

together with reasoning lead to a decision making process that classifies the radar signature with a degree of confidence. Attempts to automate the mental process of an image analyst for image interpretation have not been successful. Image processing, image understanding, and computer vision techniques have been developed but have provided only limited capabilities for automated feature extraction. This is partly due to the fact that pixel structures of terrain features vary from image to image. A computer can be used to measure the brightness and configuration of pixels in a feature, whereas an image analyst has the capability to extract and classify the feature from the image. For the purpose of developing a model that simulates the image interpretation process of an image analyst the following assumptions were made. Radar images of a terrain feature class may be characterized by sets of descriptors. Descriptors should represent primitive attributes of radar signatures. They should be easily recognized and understood by untrained personnel. Descriptors should lend themselves to measurements in the digital image domain using computer vision techniques. A set of descriptors should be chosen so that it identifies the feature class unambiguously. The characterization of a feature class may require more than one set of descriptors.

The initial investigation started with the examination of 167 synthetic aperture radar (SAR) image samples covering 17 types of terrain features. The scale of the imagery varied between approximately 1:25,000 and 1:100,000. The resolution of the imagery varied from high resolution to a resolution of about 20 feet. Based on the initial results it was realized that the number of image samples has to be significantly increased in order to obtain consistent results. The number of features was also increased.

A detailed examination of 701 SAR images covering 29 types of man-made and natural terrain features led to the identification of 52 descriptors that can be divided into five groups: spatial, intensity, textural, dimensional, and background descriptors. The headings of the five groups of descriptors were selected by expert analysts based on their experience. Each descriptor consists of attributes that are used by image analysts in their image interpretation. Table 1 lists the attributes that were used to identify and define the 52 descriptors:

The descriptors including their attributes could be arranged into a hierarchical organization as shown in Table 2. Each descriptor is designated by a key consisting of two letters that are shown in the first column of Table 2. The key "bg" for example represents a spatial descriptor that consists of a curvilinear line.

The process of identifying and defining descriptors was evolutionary. Changes were made and more changes are expected to come. Some of the

point	parallel to direction of radar beam
line	convex/concave in direction of radar beam
area	interlocking
number	bright
pattern	medium
shape	dark
orientation	no-return
brightness	intermingled intensities
single (point, line, area)	fine
group (points, lines, areas)	medium
irregular	coarse
linear	length
rectangular	width
rectilinear	diameter
curvilinear	spacing
compound	medium brightness
rectilinear with angular bend(s)	low brightness
circular/semicircular	no-return on one side
2 parallel lines	no-return on more than one side
3-4 parallel lines	on-line
more than 4 parallel lines	

Table 1
List of Attributes of Radar Descriptors

attributes were controversial, such as "2 closely spaced, parallel to radar." Figure 1 shows a radar image that includes a lake at the center of the image. The descriptors that apply to the radar signature of the lake are: single area (ca), irregular shape (cf), no-return brightness (dd), fine texture (ea), and background of medium brightness (ga). Figure 2 shows another radar image of a lake. The descriptors for that lake are: single line (ba), having a compound shape (bh), single area (ca), irregular shape (cf), no-return brightness (dd), fine texture (ea), and medium brightness (ga). The two examples show that the same feature has more than one set of descriptors.

DESCRIPTOR SETS

All descriptors that are extracted from an image of a feature form a descriptor set. A minimum of 12 image samples were analyzed for each of the 29 feature classes. A rule of thumb for the number of image samples that are needed to determine adequate descriptors and descriptor sets for characterization of a specific feature class was: increase the number of image samples until no additional image descriptors and descriptor sets are

Code	Descriptor	Category	Feature	Descriptor class
aa	SINGLE POINT	NUMBER	POINT FEATURES	SPATIAL DESCRIPTORS
ab	GROUP OF POINTS			
ac	2 CLOSELY SPACED, PARALLEL TO RADAR			
ad	IRREGULAR	PATTERN		
ae	LINEAR			
af	RECTANGULAR			
ag	RECTILINEAR	SHAPE (OF LINEAR PATTERN)		
ah	CURVILINEAR			
ai	COMPOUND			
aj	RECTILINEAR WITH ANGULAR BEND(S)			
ak	CIRCULAR/SEMICIRCULAR			
ba	SINGLE LINE	NUMBER	LINEAR FEATURES	
bb	GROUP OF LINES			
bc	2 PARALLEL LINES			
bd	3-4 PARALLEL LINES			
be	> 4 PARALLEL LINES			
bf	RECTILINEAR	SHAPE		
bg	CURVILINEAR			
bh	COMPOUND			
bi	RECTILINEAR WITH ANGULAR BEND(S)			
bj	CIRCULAR/SEMICIRCULAR			
bk	IRREGULAR	PATTERN		
bl	LINEAR			
bm	RECTANGULAR			
bn	PARALLEL TO DIRECTION OF RADAR	ORIENTATION		
bo	CONCAVE/CONVEX IN DIRECTION OF RADAR			
ca	SINGLE AREA	NUMBER	AREAL FEATURES	
cb	GROUP OF AREAS			
cc	RECTANGULAR	SHAPE		
cd	OVAL/CIRCULAR			
ce	POLYGONAL			
cf	IRREGULAR			
cg	LINEAR	PATTERN		
ch	RECTANGULAR			
ci	INTERLOCKING			
da	BRIGHT	BRIGHTNESS	INTENSITY DESCRIP- TORS	
db	MEDIUM			
dc	DARK			
dd	NO-RETURN			
de	INTERMINGLED INTENSITIES	PATTERN		
ea	FINE	TEXTURAL DESCRIPTORS		
eb	MEDIUM			
ec	COARSE			
fa	LENGTH	DIMENSIONAL DESCRIPTORS		
fb	WIDTH			
fc	DIAMETER			
fd	SPACING			
ga	MEDIUM BRIGHTNESS	BACKGROUND DESCRIPTORS		
gb	LOW BRIGHTNESS			
gc	NO-RETURN, ONE SIDE			
gd	NO-RETURN, MORE THAN ONE SIDE			
ge	ON-LINE			

Table 2
Hierarchical Organization of Radar Descriptors

Figure 1
Radar Image of Small Lake

Figure 2
Radar Image of Larger Lake

discovered, then take twice that number as a sufficient number for image samples. Table 3 shows the results of the analysis of 13 image samples of the feature "Rail Lines." The feature Rail Lines consists of 8 descriptors and 18 descriptor sets. The feature samples numbered 3 to 9 consist of the same descriptors and descriptor sets. The feature samples numbered 10 and 11 also have identical descriptors and descriptor sets. The columns "set number" and "image reference number" of Table 3 are of no concern to this report but were used in the image analysis. Table 4 shows the number of descriptors and descriptor sets of the 29 man-made and natural terrain features that were extracted and identified in the analysis of the 701 image samples. The structures of the descriptor sets were investigated to determine whether there are rules by which the descriptor sets can be represented in terms of the descriptors. The investigation showed that the descriptor sets could be represented by Boolean expressions. For example the set of descriptors for the feature Rail Lines could be expressed as:

$$(ba + bc + bd) * (bf + bg + bh) * (da + db)$$

Table 3
Descriptor Sets of 13
Samples of Rail Lines
Radar Images

RAIL LINES

13	12	11	10	9	8	7	6	5	4	3	2	1	FEATURE NUMBER				
													SET NUMBER				
													IMAGE REFERENCE NUMBER				
													aa	SINGLE POINT	NUMBER	POINT FEATURES	SPATIAL DESCRIPTORS
													ab	GROUP OF POINTS	NUMBER	POINT FEATURES	SPATIAL DESCRIPTORS
													ac	2 CLOSELY SPACED, PARALLEL TO RADAR	NUMBER	POINT FEATURES	SPATIAL DESCRIPTORS
													ad	IRREGULAR	PATTERN	POINT FEATURES	SPATIAL DESCRIPTORS
													ae	LINEAR	PATTERN	POINT FEATURES	SPATIAL DESCRIPTORS
													af	RECTANGULAR	PATTERN	POINT FEATURES	SPATIAL DESCRIPTORS
													ag	RECTILINEAR	SHAPE (OF LINEAR PATTERN)	POINT FEATURES	SPATIAL DESCRIPTORS
													ah	CURVILINEAR	SHAPE (OF LINEAR PATTERN)	POINT FEATURES	SPATIAL DESCRIPTORS
													ai	COMPOUND	SHAPE (OF LINEAR PATTERN)	POINT FEATURES	SPATIAL DESCRIPTORS
													aj	RECTILINEAR WITH ANGULAR BEND(S)	SHAPE (OF LINEAR PATTERN)	POINT FEATURES	SPATIAL DESCRIPTORS
													ak	CIRCULAR/SEMICIRCULAR	SHAPE (OF LINEAR PATTERN)	POINT FEATURES	SPATIAL DESCRIPTORS
		●	●	●	●	●	●	●	●	●			ba	SINGLE LINE	NUMBER	LINEAR FEATURES	SPATIAL DESCRIPTORS
													bb	GROUP OF LINES	NUMBER	LINEAR FEATURES	SPATIAL DESCRIPTORS
●													bc	2 PARALLEL LINES	NUMBER	LINEAR FEATURES	SPATIAL DESCRIPTORS
	●										●	●	bd	3–4 PARALLEL LINES	NUMBER	LINEAR FEATURES	SPATIAL DESCRIPTORS
													be	> 4 PARALLEL LINES	NUMBER	LINEAR FEATURES	SPATIAL DESCRIPTORS
		●	●								●		bf	RECTILINEAR	SHAPE	LINEAR FEATURES	SPATIAL DESCRIPTORS
●	●												bg	CURVILINEAR	SHAPE	LINEAR FEATURES	SPATIAL DESCRIPTORS
				●	●	●	●	●	●	●		●	bh	COMPOUND	SHAPE	LINEAR FEATURES	SPATIAL DESCRIPTORS
													bi	RECTILINEAR WITH ANGULAR BEND(S)	SHAPE	LINEAR FEATURES	SPATIAL DESCRIPTORS
													bj	CIRCULAR/SEMICIRCULAR	SHAPE	LINEAR FEATURES	SPATIAL DESCRIPTORS
													bk	IRREGULAR	PATTERN	LINEAR FEATURES	SPATIAL DESCRIPTORS
													bl	LINEAR	PATTERN	LINEAR FEATURES	SPATIAL DESCRIPTORS
													bm	RECTANGULAR	PATTERN	LINEAR FEATURES	SPATIAL DESCRIPTORS
													bn	PARALLEL TO DIRECTION OF RADAR	ORIENTATION	LINEAR FEATURES	SPATIAL DESCRIPTORS
													bo	CONCAVE/CONVEX IN DIRECTION OF RADAR	ORIENTATION	LINEAR FEATURES	SPATIAL DESCRIPTORS
													ca	SINGLE AREA	NUMBER	AREAL FEATURES	SPATIAL DESCRIPTORS
													cb	GROUP OF AREAS	NUMBER	AREAL FEATURES	SPATIAL DESCRIPTORS
													cc	RECTANGULAR	SHAPE	AREAL FEATURES	SPATIAL DESCRIPTORS
													cd	OVAL/CIRCULAR	SHAPE	AREAL FEATURES	SPATIAL DESCRIPTORS
													ce	POLYGONAL	SHAPE	AREAL FEATURES	SPATIAL DESCRIPTORS
													cf	IRREGULAR	SHAPE	AREAL FEATURES	SPATIAL DESCRIPTORS
													cg	LINEAR	PATTERN	AREAL FEATURES	SPATIAL DESCRIPTORS
													ch	RECTANGULAR	PATTERN	AREAL FEATURES	SPATIAL DESCRIPTORS
													ci	INTERLOCKING	PATTERN	AREAL FEATURES	SPATIAL DESCRIPTORS
		●	●								●	●	da	BRIGHT	BRIGHTNESS	INTENSITY DESCRIPTORS	
●	●			●	●	●	●	●	●	●			db	MEDIUM	BRIGHTNESS	INTENSITY DESCRIPTORS	
													dc	DARK	BRIGHTNESS	INTENSITY DESCRIPTORS	
													dd	NO-RETURN	BRIGHTNESS	INTENSITY DESCRIPTORS	
													de	INTERMINGLED INTENSITIES	PATTERN	INTENSITY DESCRIPTORS	
													ea	FINE	TEXTURAL DESCRIPTORS		
													eb	MEDIUM	TEXTURAL DESCRIPTORS		
													ec	COARSE	TEXTURAL DESCRIPTORS		
													fa	LENGTH	DIMENSIONAL DESCRIPTORS		
													fb	WIDTH	DIMENSIONAL DESCRIPTORS		
													fc	DIAMETER	DIMENSIONAL DESCRIPTORS		
													fd	SPACING	DIMENSIONAL DESCRIPTORS		
													ga	MEDIUM BRIGHTNESS	BACKGROUND DESCRIPTORS		
													gb	LOW BRIGHTNESS	BACKGROUND DESCRIPTORS		
													gc	NO-RETURN, ONE SIDE	BACKGROUND DESCRIPTORS		
													gd	NO-RETURN, MORE THAN ONE SIDE	BACKGROUND DESCRIPTORS		
													ge	ON-LINE	BACKGROUND DESCRIPTORS		

The symbols ba, bc, bd, bf, bg, bh, da, and db represent descriptors listed in Table 1. The plus sign (+) stands for "or" and the times sign (*) for "and."

Feature	ND	NS	Feature	ND	NS
Aircraft	12	97	POL Storage	8	3
Breakwaters	8	8	Racing Ovals	13	3
Bridges	10	4	Rail Lines	8	18
Buildings	9	7	Rail Yards	7	4
Canals	9	24	Residential Areas	11	80
Causeways	7	8	Rivers/Streams	4	2
Croplands	11	36	Roads	6	6
Dams	8	6	Runways	3	1
Fences	7	3	Ships	17	56
Forests	10	54	Transmission Lines	6	3
Golf Courses	5	1	Tree Lines	8	24
Lake Ice	9	8	Vehicles on Road	3	1
Lakes/Ponds	9	4	Wetlands	9	2
Mountains	14	4			
Parking Lots	11	23			
Piers/Docks	15	12			

Table 4
Number of Descriptors (column ND) and Number of Descriptor Sets (column NS) of the 29 Man-Made and Natural Terrain Features

The rules for the descriptor sets were incorporated into a knowledge based expert system (KBES). There are two ways to use the KBES. First, the input to the KBES are descriptors. The descriptors for example can be extracted from an image feature. If the descriptors form a set that belongs to a feature descriptor set the answer of the KBES is the name of the feature. Otherwise, the answer is "unknown." Second, the input to the KBES is the name of a feature. The answer of the KBES is a list of descriptors that form the descriptor set of the entered feature. The image analyst can use the KBES to answer the question whether the recognized descriptors belong to a feature. On the other hand, if a feature is suspected the image analyst can call the KBES to list the descriptors of the suspected feature.

The KBES was used to determine ambiguities or redundancies of the descriptor sets. The descriptors ba, bh, and dd for example form a descriptor set for the terrain feature Canals. In addition to Canals the KBES also lists the features Rivers and Roads. Approximately 20% of the examples that were tested showed ambiguities. The ambiguities were

investigated to determine the possibility of their removal. The 502 descriptor sets that were developed by the expert image analysts could be reduced to 478 without affecting the functioning of the KBES adversely. In addition to the redundancy removal some descriptor sets have to be modified or augmented, and in some cases additional rules are needed.

TESTS

The purpose of the tests was to evaluate and verify the usefulness of the concept of radar descriptors and descriptor sets. The tests were organized into two phases and taken by two groups of people.

The test material for phase 1 included a set of training material and a set of test graphics. The training material set numbered 11 pages and included "Definitions and Examples," a "Feature Descriptor Matrix," and "Conditional/Action Rules for Descriptor into Sets." The tables numbered 5 to 9 show examples of the training material. The descriptor matrix of Table 6 was derived from Table 2 and was designed as a simpler version for the tests. This matrix includes only 40 descriptors rather than 52. The graphics test set consisted of 52 graphic test figures that contained the radar descriptors. The graphic test figures were included in the test program because they were considered to be more appropriate than radar imagery for the initial introduction of the concept of radar descriptors. Figures 3 and 4 show examples of the graphics test figures that have no background. The test material of phase 2 consisted of 35 radar images which contained most of the radar descriptors. The test material was carefully examined, reviewed, and modified by personnel of the U.S. Army Engineer Topographic Laboratories (USAETL), the U.S. Army Intelligence Center and School (USAICS), and the contractor. The final test material for phases 1 and 2 was furnished by the contractor.

The first test group consisted of 14 professionals of USAETL having varying degrees of experience in image interpretation. In addition to taking the tests this group was also tasked to review and to comment on the test procedures. The second test group included a class of 20 students of USAICS who had no experience in image interpretation.

The phase 1 tests included the familiarization with the descriptors using the training material and the extraction of descriptors from the graphics set. The first group tested needed between 2 and 5 hours to complete the phase 1 test. The spread in time was primarily due to the extent of the comments provided by the persons. The extraction and identification of descriptors from the graphics set did not present any real problems. Based on the comments provided by the test group and discussions with the instructors of the Intelligence School, changes of the test material were made to eliminate controversial definitions and ambiguous

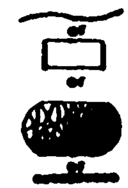
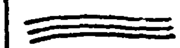
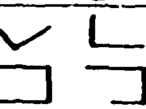
	FEATURE DESCRIPTOR	DEFINITION	EXAMPLE OF FEATURE	GRAPHIC EXAMPLE	IMAGE EXAMPLE
NUMBER	Single Line	A continuous line, either straight or curved. The term "single line" also refers to the dimensionless linear interface between two areas having different tones or textures ("line" is defined as a feature having a length-width ratio of 10:1 or more. Also, a series of points that are in contact with one another.	Road, fence or dam		
	Group Of Lines	Two or more non-parallel lines.	Buildings, ships and aircraft		
	Two Parallel Lines	Two closely-spaced lines that remain approximately equidistant throughout their length.	Divided highway		
	Three To Four Parallel Lines	Three or four closely-spaced lines that remain approximately equidistant throughout their length.	Three-track railroad line		
	More Than Four Parallel Lines	Four or more closely-spaced lines that remain approximately equidistant throughout their length.	Railroad yard		
SHAPE	Rectilinear Line	A straight line.	Runways, power line cuts		
	Curvilinear Line	A continuously curving line.	Roads, railroads		
	Compound Line	A line that is made up of rectilinear and curvilinear segments.	Roads, railroads		
	Rectilinear Lines With Angular Bend (s)	Same as "rectilinear line" but with one or more angular bends.	Buildings, docks, powerline cuts		
	Circular/Semi-Circular Lines	A line that describes a circle or half-circle.	POL tanks		

Table 5
Definitions and Examples of Line Feature Descriptors

20HCE

IMAGE NUMBER			
SINGLE POINT	NUMBER	POINT FEATURES	SPATIAL DESCRIPTORS
GROUP OF POINTS			
IRREGULAR	PATTERN		
LINEAR			
RECTANGULAR			
RECTILINEAR	SHAPE (OF LINEAR PATTERN)		
CURVILINEAR			
COMPOUND			
RECTILINEAR WITH ANGULAR BEND(S)			
CIRCULAR/SEMICIRCULAR			
SINGLE LINE	NUMBER	LINEAR FEATURES	
GROUP OF LINES			
2 PARALLEL LINES			
3-4 PARALLEL LINES			
> 4 PARALLEL LINES			
RECTILINEAR	SHAPE		
CURVILINEAR			
COMPOUND			
RECTILINEAR WITH ANGULAR BEND(S)			
CIRCULAR/SEMICIRCULAR			
IRREGULAR	PATTERN		
LINEAR			
RECTANGULAR			
SINGLE AREA	NUMBER	AREAL FEATURES	
GROUP OF AREAS			
RECTANGULAR	SHAPE		
OVAL/CIRCULAR			
POLYGONAL			
IRREGULAR			
LINEAR	PATTERN		
RECTANGULAR			
INTERLOCKING			
BRIGHT	BRIGHTNESS		
MEDIUM			
NO-RETURN			
INTERMINGLED INTENSITIES			
MEDIUM BRIGHTNESS	BACKGROUND DESCRIPTORS		
LOW BRIGHTNESS			
DARK			

Table 6
Feature Descriptor Matrix

DESCRIPTOR (CONDITION)		RULE (ACTION)
NUMBER	SINGLE POINT GROUP OF POINTS	GO TO BRIGHTNESS GO TO PATTERN
PATTERN	IRREGULAR LINEAR RECTANGULAR	GO TO BRIGHTNESS GO TO SHAPE GO TO BRIGHTNESS
SHAPE (OF LINEAR PATTERN)	RECTILINEAR CURVILINEAR COMPOUND RECTILINEAR W/ ANGULAR BEND(S) CIRCULAR/SEMICIRCULAR	GO TO BRIGHTNESS
BRIGHTNESS	BRIGHT MEDIUM NO-RETURN	GO TO BACKGROUND
BACKGROUND	MEDIUM BRIGHTNESS LOW BRIGHTNESS DARK	END END END

Table 7
Condition/Action Rules for
Organizing Descriptors into Sets: Point Features

DESCRIPTOR (CONDITION)		RULE (ACTION)
NUMBER	SINGLE AREA GROUP OF AREAS	GO TO SHAPE GO TO SHAPE
SHAPE	RECTANGULAR OVAL/CIRCULAR POLYGONAL IRREGULAR	IF SINGLE AREA, GO TO BRIGHTNESS; IF GROUP OF AREAS, GO TO PATTERN.
PATTERN	LINEAR RECTANGULAR INTERLOCKING	GO TO BRIGHTNESS
BRIGHTNESS	BRIGHT MEDIUM NO-RETURN INTERMINGLED	GO TO BACKGROUND
BACKGROUND	MEDIUM BRIGHTNESS LOW BRIGHTNESS DARK	END

Table 9
Condition/Action Rules for
Organizing Descriptors into Sets: Areal Features

	DESCRIPTOR (CONDITION)	RULE (ACTION)
NUMBER	SINGLE LINE GROUP OF LINES 2 PARALLEL LINES 3-4 PARALLEL LINES > 4 PARALLEL LINES	GO TO SHAPE
SHAPE	RECTILINEAR CURVILINEAR COMPOUND RECTILINEAR W/ ANGULAR BEND(S) CIRCULAR/SEMICIRCULAR	IF ONE OR TWO LINES, GO TO BRIGHTNESS; OTHERWISE, GO TO PATTERN.
PATTERN	IRREGULAR LINEAR RECTANGULAR	GO TO BRIGHTNESS
BRIGHTNESS	BRIGHT MEDIUM NO-RETURN	GO TO BACKGROUND
BACKGROUND	MEDIUM BRIGHTNESS LOW BRIGHTNESS DARK ON-LINE	END

Table 8
Condition/Action Rules for
Organizing Descriptors into Sets: Linear Features

descriptors. The second group (USAICS students) were using the revised test material. The phase 1 tests were scheduled at the start of the 16 weeks course "Imagery Analyst Course 96D10." The students completed the phase 1 tests in 3 hours with a 100% success. Two more phase 1 tests are scheduled for future classes of the same course.

The phase 2 tests that included the extraction and identification of descriptors from radar imagery were conducted only by personnel from USAETL. The problems that were found were the need to redefine few descriptors and to develop additional instructions concerning the background. The phase 2 tests are also included in the USAICS course, but were not completed at the time of this writing.

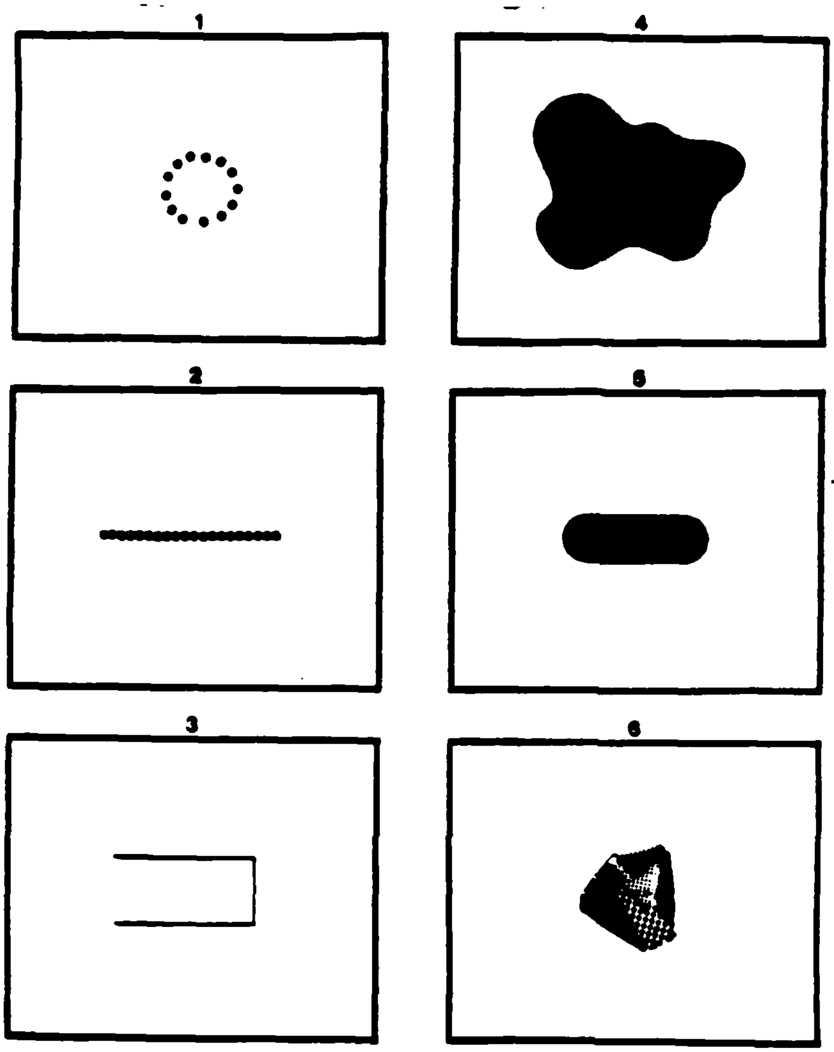


Figure 3
Test Graphics Numbered 1 to 6

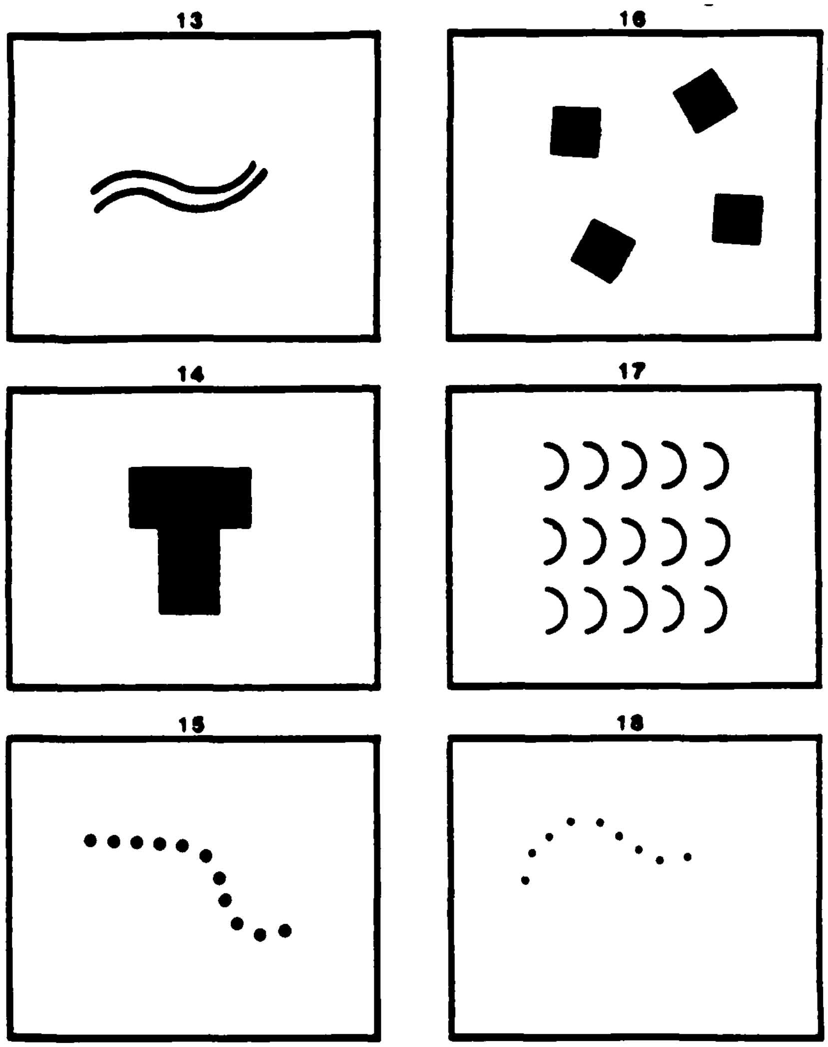


Figure 4
Test Graphics Numbered 13 to 18

DISCUSSION

The research and development of the concepts of radar descriptors and descriptor sets has shown that their application can improve the process of image analysis. Background descriptors proved to be a problem in some cases when actual radar imagery rather than graphic figures were involved. It was found that image analysts conduct their analysis in terms of similar procedures and mental processes, but with a degree of "personal variance." Imprecise and ambiguous definitions and rules are sometimes the results of the "personal variance." Future research must concentrate on these problems to develop a better model of the perception and interpretation of the image analyst. The representation of descriptor sets in terms of Boolean expressions must be considered as a beginning of the development of unambiguous characterization of features. Because the development of useful descriptors is evolutionary, descriptors, descriptor sets, and KBESs will undergo changes, augmentations, and revisions in the future. Automated detection and recognition of radar descriptors will be addressed in the next phase of research and development.

CONCLUSIONS

The following conclusions could be reached: (1) The concept of radar descriptors and descriptor sets is a viable approach to improve the image analysis process; (2) The development of useful descriptors and descriptor sets is an evolutionary process. Presently the development is still in an early phase; and (3) The techniques developed so far still require the man in the loop.

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